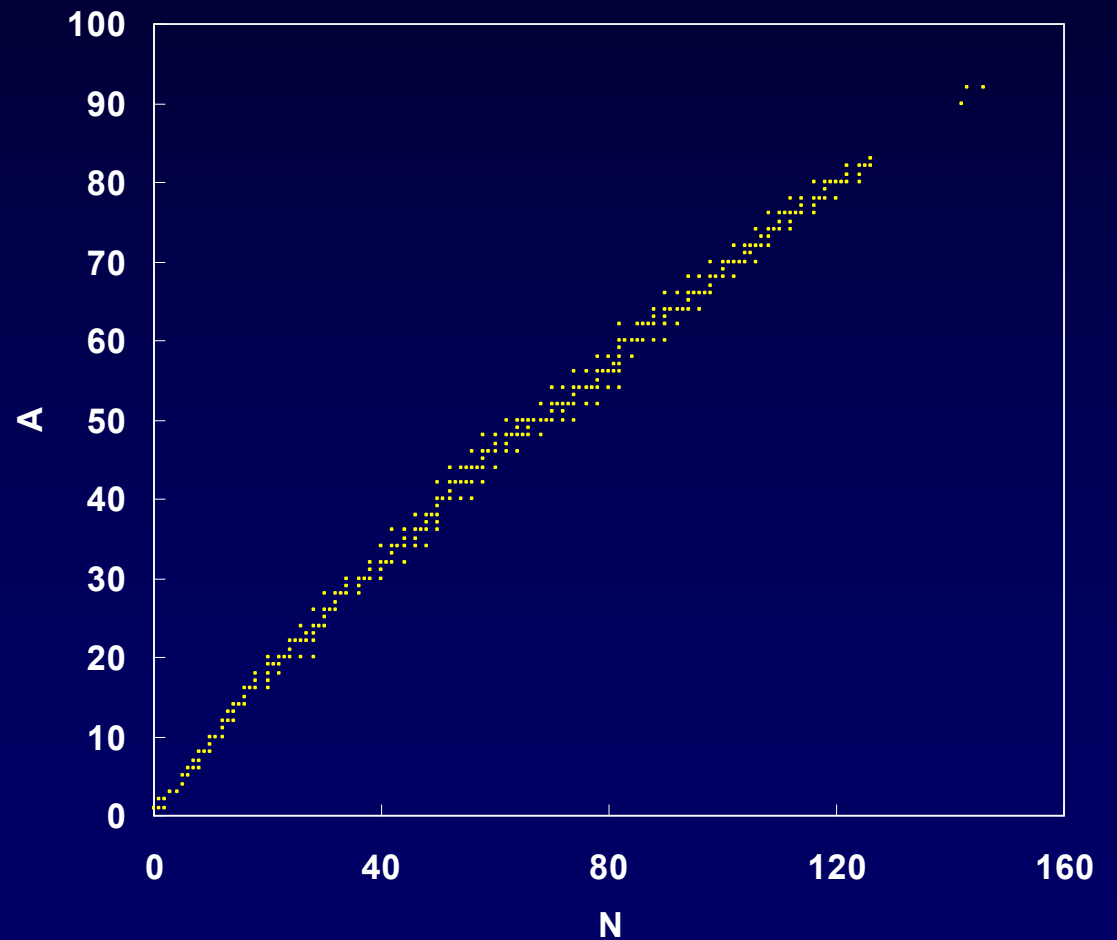
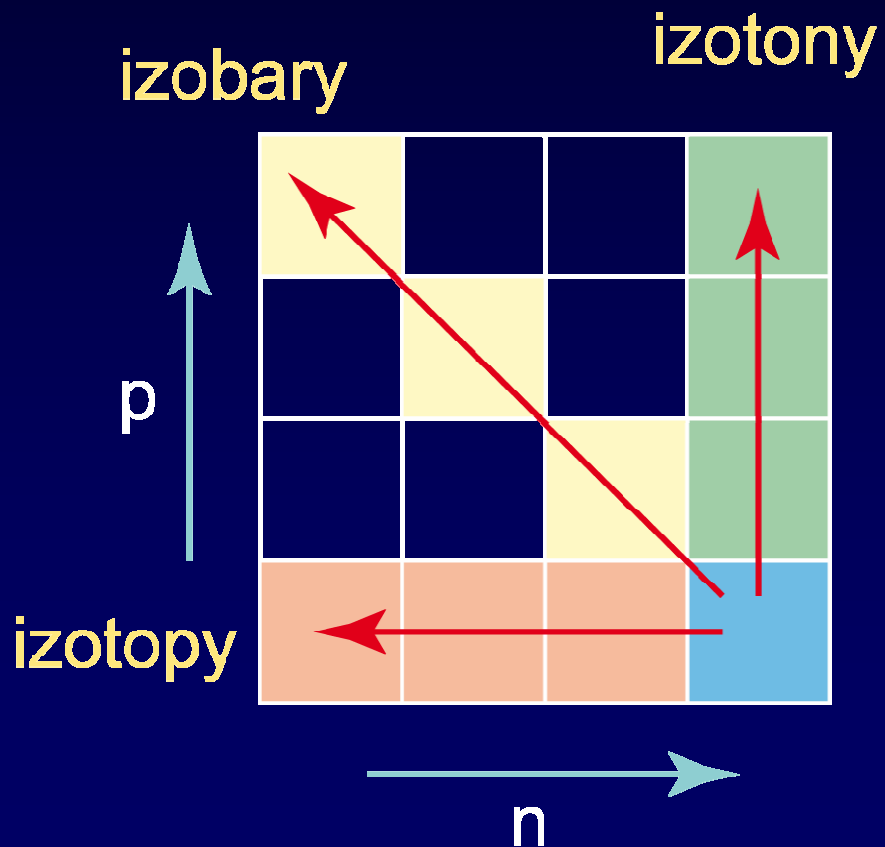


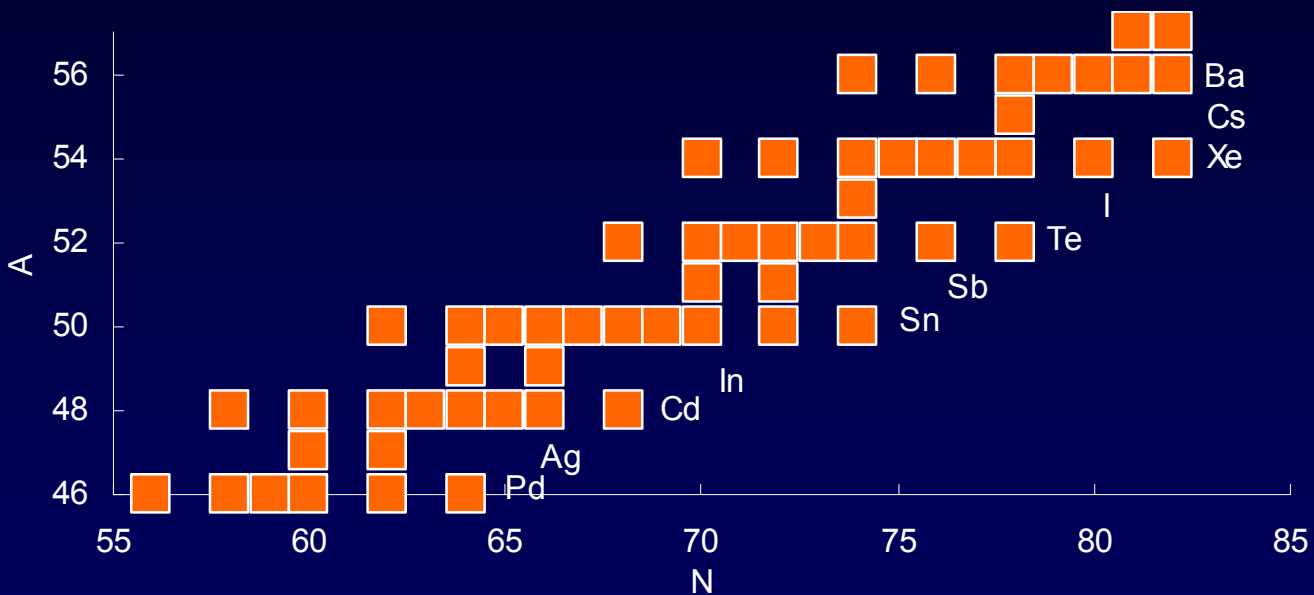
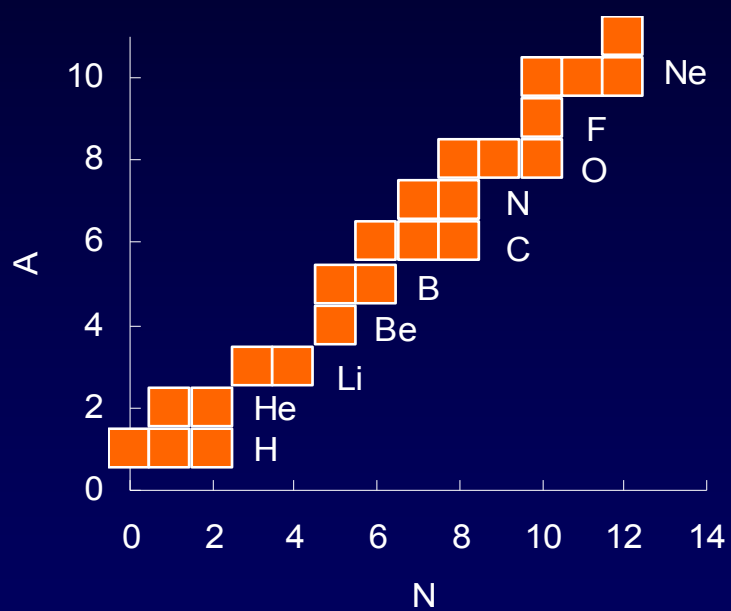
# Izotopy

# Izotopy

Stejné atomové číslo, různé hmotové číslo - různý počet neutronů.



# Izotopy



# Vazebná energie jádra

proton: 1,007593 daltonů =  $1,6726231 \times 10^{-27}$  kg

neutron: 1,008982 daltonů

elektron: 0,000548756 daltonů =  $9,10093897 \times 10^{-31}$  kg

hmotnostní úbytek  $\delta = W - M$

W – součet hmotností jednotlivých částic

M – hmotnost spojených částic

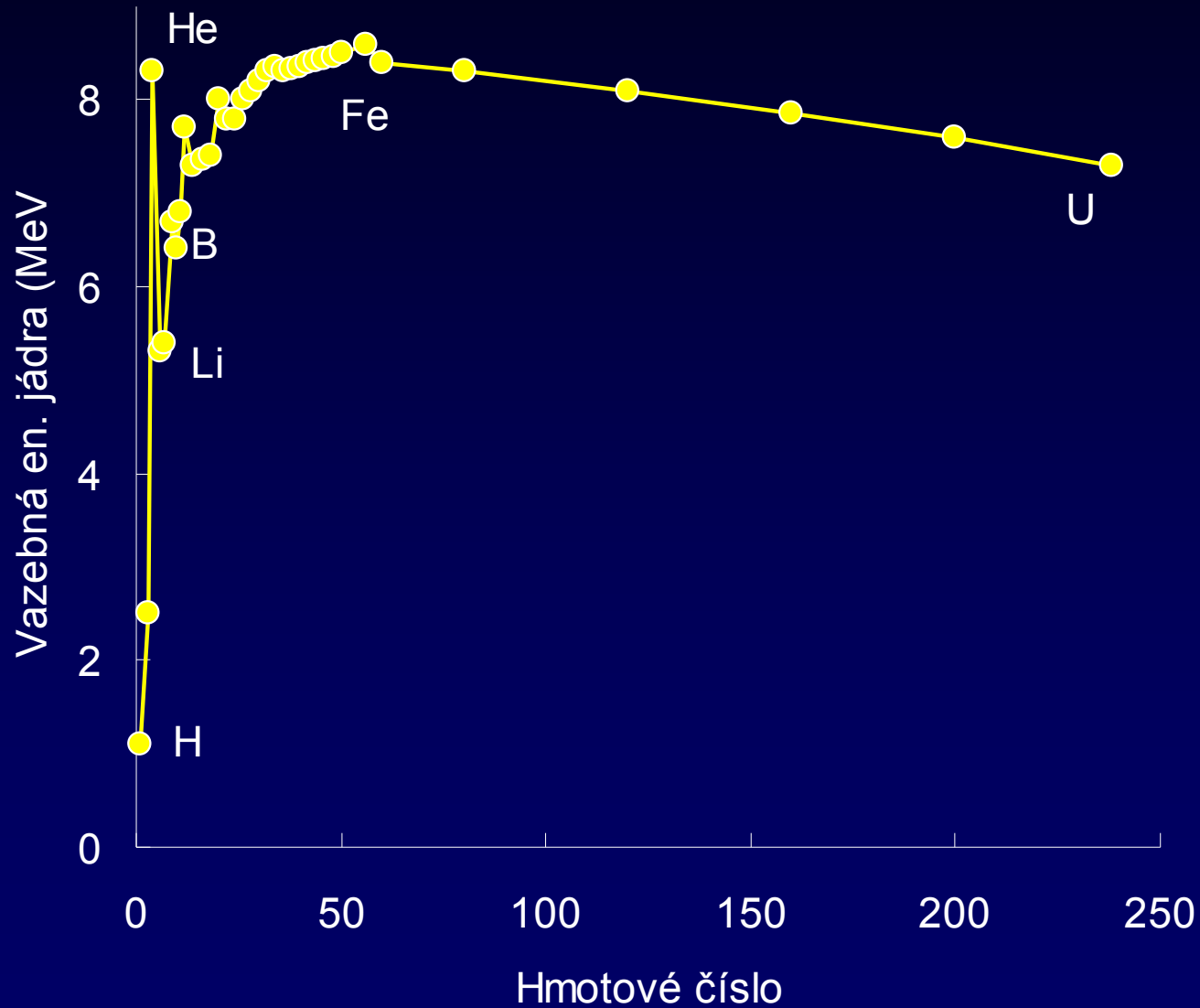
$${}^4\text{He} = 2m_p + 2m_n + 2m_e = 4,034248 \text{ daltonů}$$

$$m({}^4\text{He}) = 4,003873 \text{ daltonů}$$

$\delta = 0,030375$  daltonů (tj. 28,28 MeV – vazebná energie)

$$E = m c^2$$

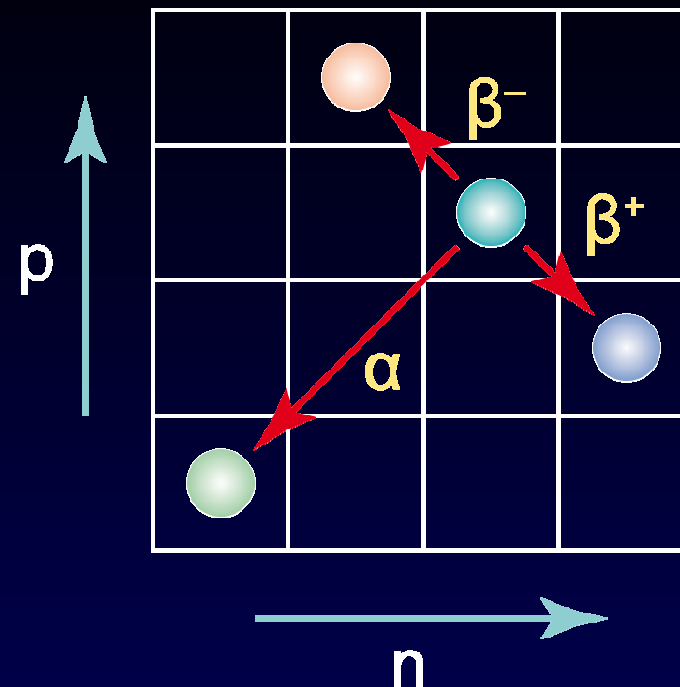
# Vazebná energie jádra



# **Nestabilní izotopy (radiogenní)**

# Rozpad nestabilního a vybuzeného jádra

$$dN/dt = -\lambda N$$



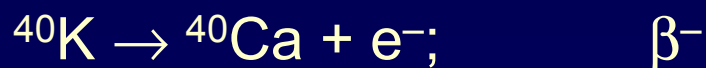
$\gamma$ -záření:



$\alpha$ -rozpad:



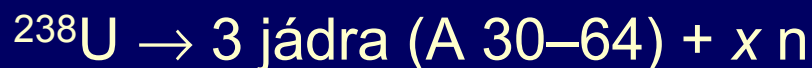
$\beta$ -rozpad:



záchyt elektronu:



spontánní rozpad:



*fission track* datování

# Rychlost rozpadu

$$\frac{dN}{dt} = -\lambda N \quad \text{Rychlost}$$

$$\int_{N_0}^N \frac{dN}{N} = \int_0^t -\lambda dt$$

$$\ln \frac{N}{N_0} = -\lambda t$$

$$N = N_0 e^{-\lambda t}$$

$$t_{1/2} = \frac{\ln 2}{\lambda} \quad \text{Poločas rozpadu}$$

$$D = P_0 - P \quad D - \text{daughter, } P - \text{parent}$$

$$D = P e^{\lambda t} - P = P(e^{\lambda t} - 1)$$

$$D = D_0 + P(e^{\lambda t} - 1)$$

$${}^{87}\text{Rb} = {}^{87}\text{Sr} + e^{-}$$

$${}^{87}\text{Sr} = {}^{87}\text{Sr}_0 + {}^{87}\text{Rb}(e^{\lambda t} - 1)$$

$$\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}} = \frac{{}^{87}\text{Sr}_0}{{}^{86}\text{Sr}} + \frac{{}^{87}\text{Rb}}{{}^{86}\text{Sr}}(e^{\lambda t} - 1)$$



# Geochronologie

$$D = P_0 - P$$

$$y = a + bx \quad \text{rovnice přímky}$$

$$b = e^{\lambda t} - 1$$

$$t = \frac{1}{\lambda} \ln(b + 1)$$

$$b = \frac{\Delta D}{\Delta P}$$

Nyquist et al. (1990) – meteorit Bholghati  
– stáří Sluneční soustavy

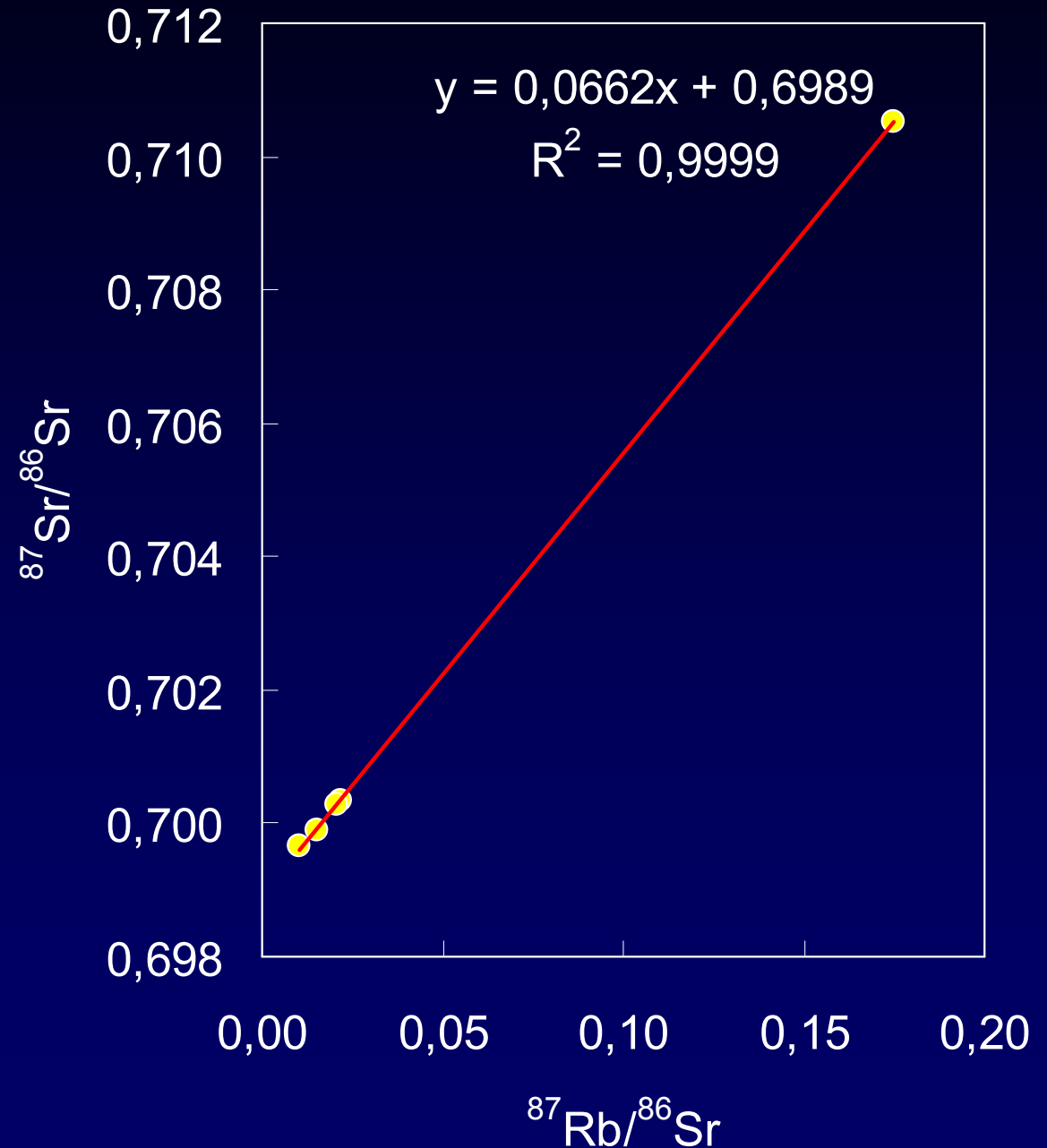
$$\frac{{}^{87}\text{Sr}}{{}^{86}\text{Sr}} = 0,6989 + 0,0662 \frac{{}^{87}\text{Rb}}{{}^{86}\text{Sr}}$$

$$(e^{\lambda t} - 1) = 0,0662$$

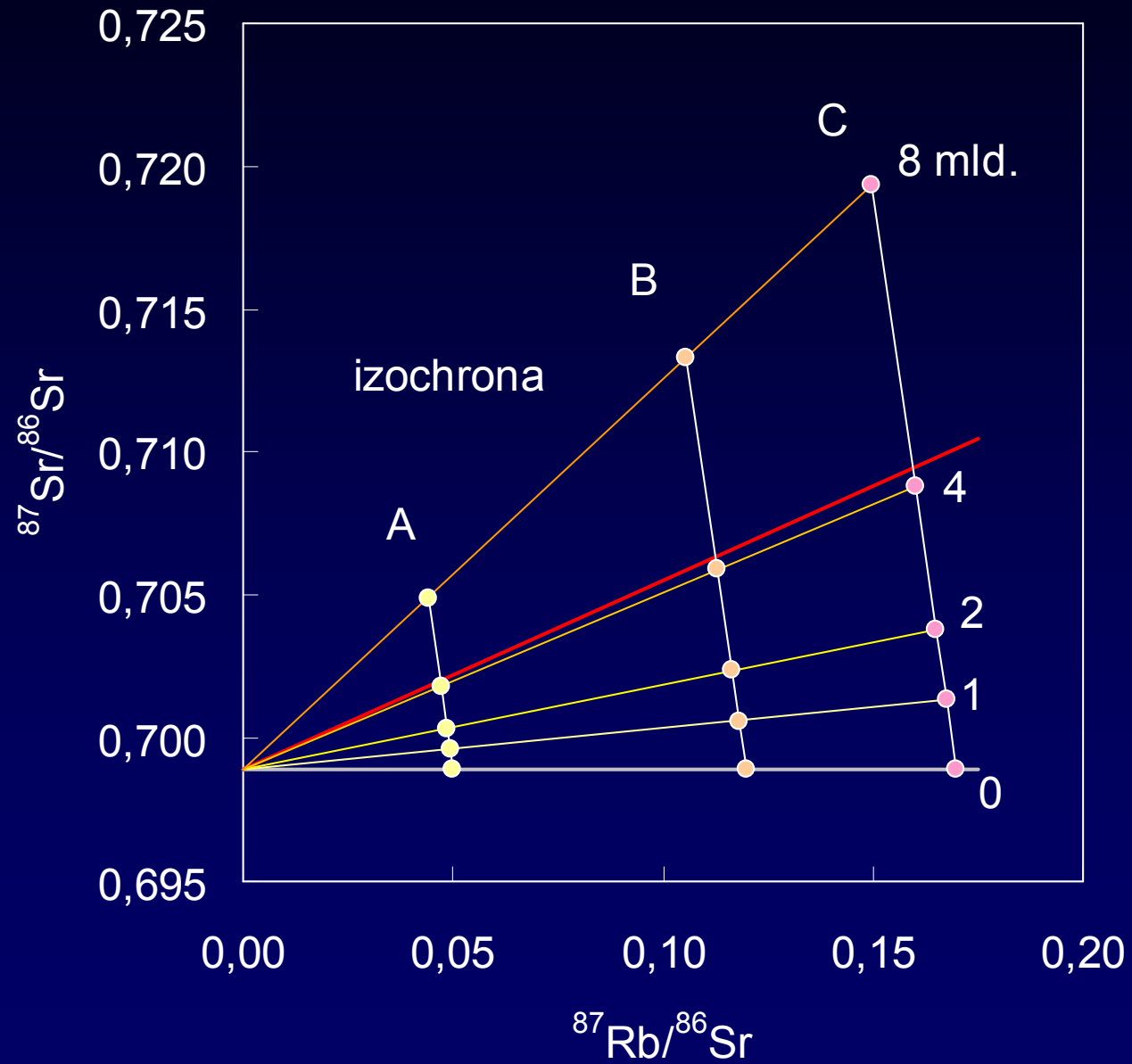
$$\lambda = 1,42 \times 10^{-11} \text{ rok}^{-1}$$

$$t = \frac{1}{1,42 \times 10^{-11}} \ln(1,0662)$$

$$t = 4,51 \times 10^9 \text{ let} = 4,51 \text{ miliardy let}$$



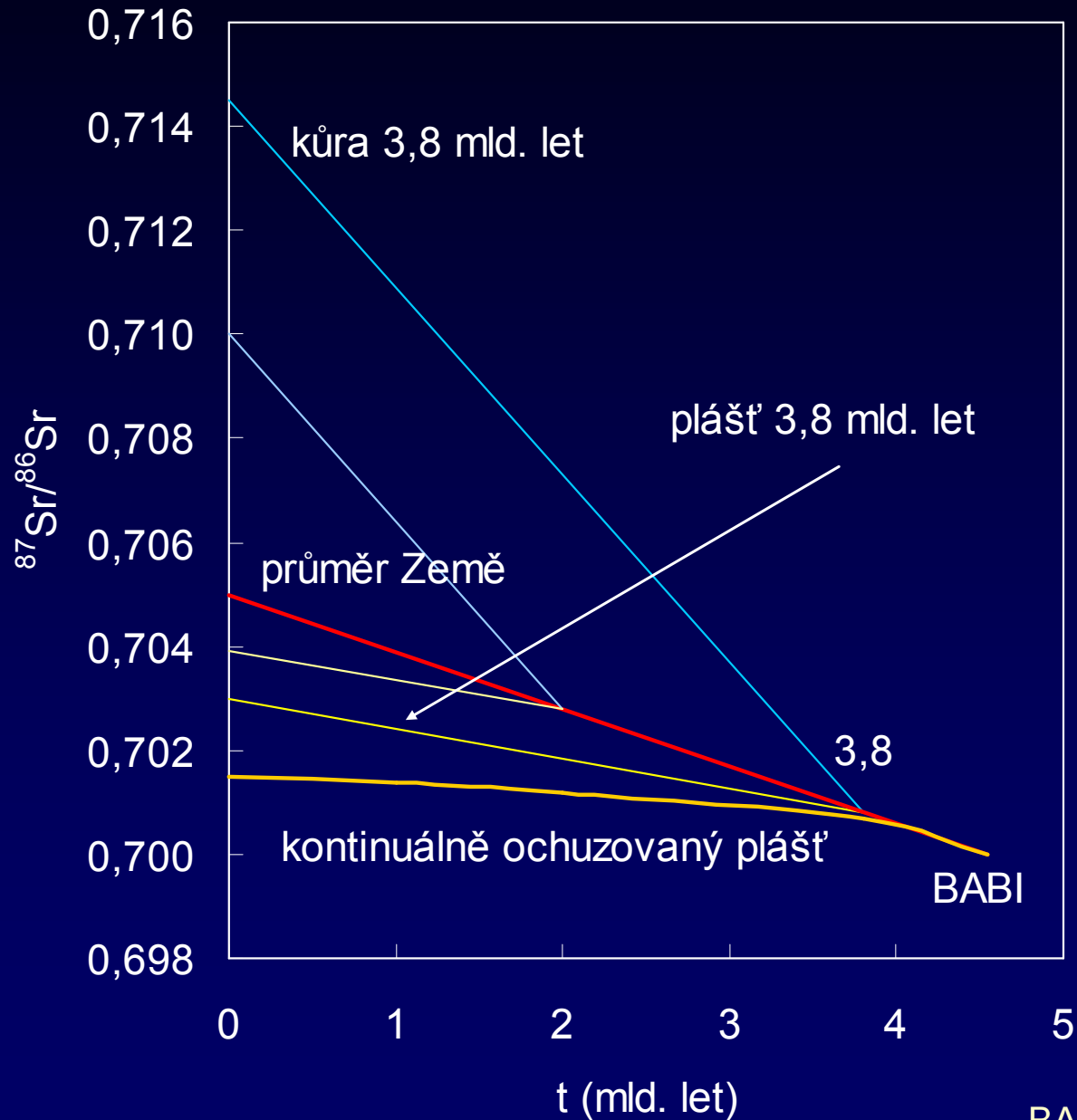
# Izochrony



# Užitečné systémy

rodič	dceřinný produkt	rozpad	$\lambda$ ( $\times 10^{12}$ rok $^{-1}$ )	$t_{1/2}$ ( $\times 10^{-9}$ let)	poměr
$^{40}\text{K}$	$^{40}\text{Ar}$ , $^{40}\text{Ca}$	$\beta^+$ , $\beta^-$	554,3	1,28	$^{40}\text{Ar}/^{36}\text{Ar}$
$^{87}\text{Rb}$	$^{87}\text{Sr}$	$\beta^-$	14,2	48	$^{87}\text{Sr}/^{86}\text{Sr}$
$^{138}\text{La}$	$^{138}\text{Ce}$	$\beta^-$	2,67	259	$^{138}\text{Ce}/^{142}\text{Ce}$ , $^{138}\text{Ce}/^{136}\text{Ce}$
$^{147}\text{Sm}$	$^{143}\text{Nd}$	$\alpha$	6,54	106	$^{143}\text{Nd}/^{144}\text{Nd}$
$^{176}\text{Lu}$	$^{176}\text{Hf}$	$\beta^-$	19,4	36	$^{176}\text{Hf}/^{177}\text{Hf}$
$^{187}\text{Re}$	$^{187}\text{Os}$	$\beta^-$	16,4	42,3	$^{187}\text{Os}/^{186}\text{Os}$ , $^{187}\text{Os}/^{188}\text{Os}$
$^{232}\text{Th}$	$^{208}\text{Pb}$ , $^4\text{He}$	$\alpha$	49,48	14	$^{208}\text{Pb}/^{204}\text{Pb}$ , $^3\text{He}/^4\text{He}$
$^{235}\text{U}$	$^{207}\text{Pb}$ , $^4\text{He}$	$\alpha$	984,9	0,707	$^{207}\text{Pb}/^{204}\text{Pb}$ , $^3\text{He}/^4\text{He}$
$^{238}\text{U}$	$^{206}\text{Pb}$ , $^4\text{He}$	$\alpha$	155,1	4,47	$^{206}\text{Pb}/^{204}\text{Pb}$ , $^3\text{He}/^4\text{He}$

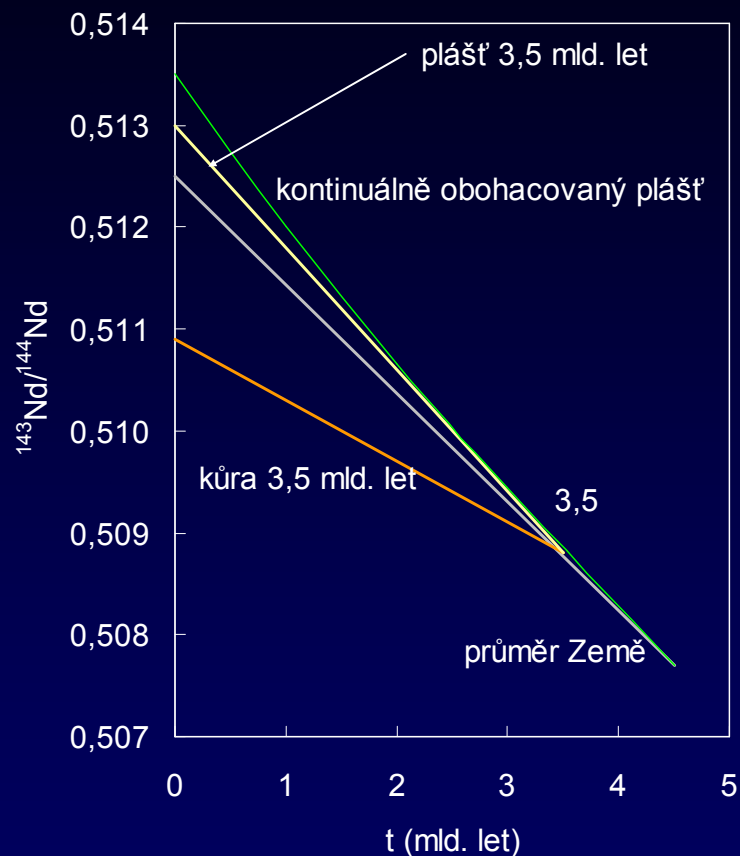
# $^{87}\text{Rb}-^{87}\text{Sr}$



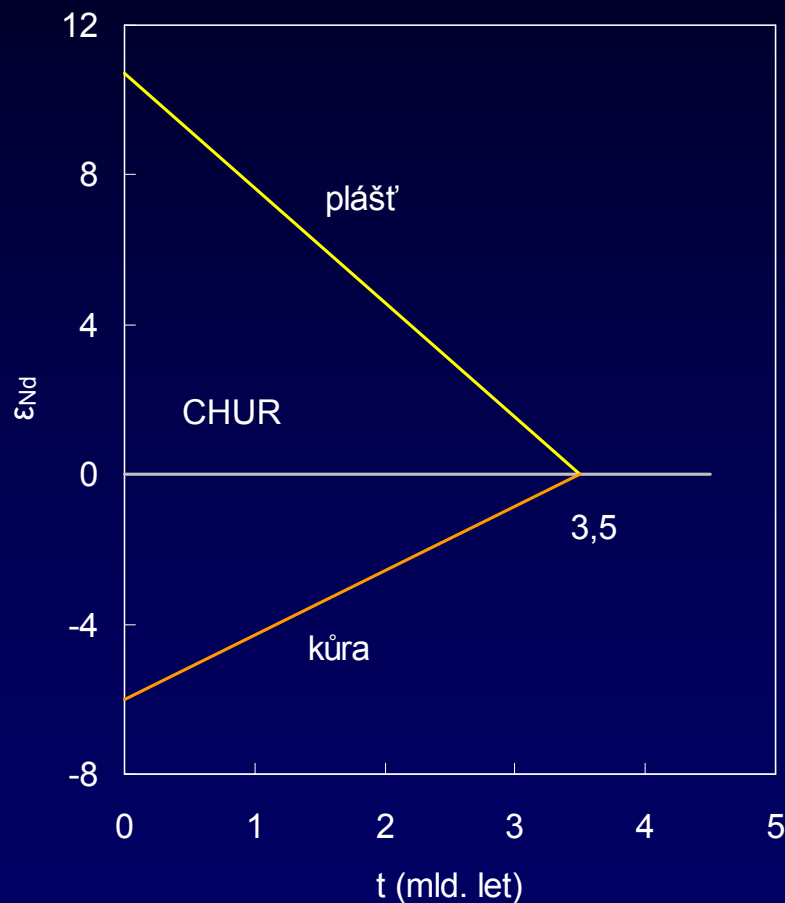
kůra je nabohacována na Rb frakcionací, výrazné změny ve světlých horninách, malé v tmavých

BABI (best initial basaltic achondrite)

# $^{147}\text{Sm}-^{143}\text{Nd}$



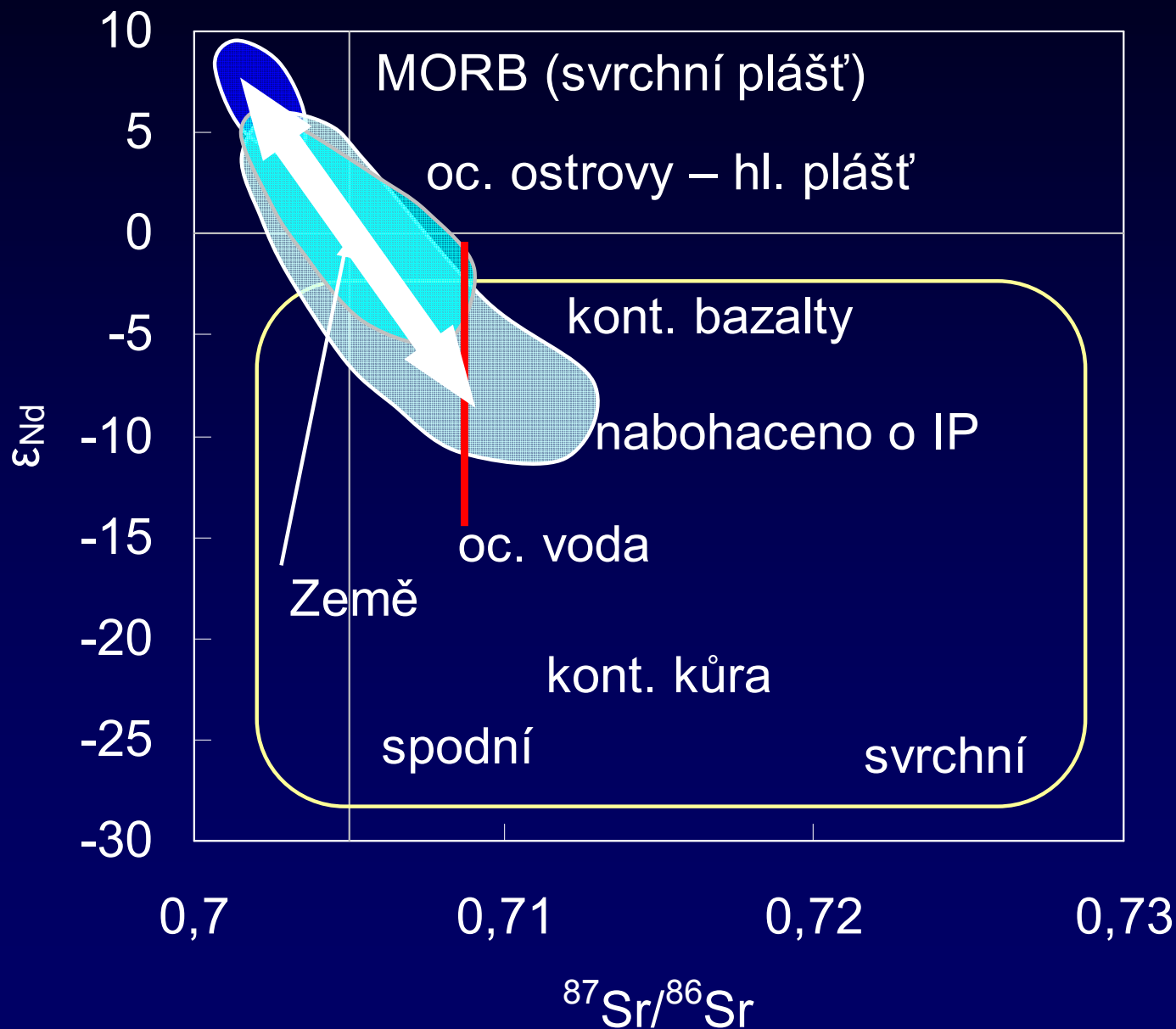
opačné chování než  $^{87}\text{Rb}-^{87}\text{Sr}$



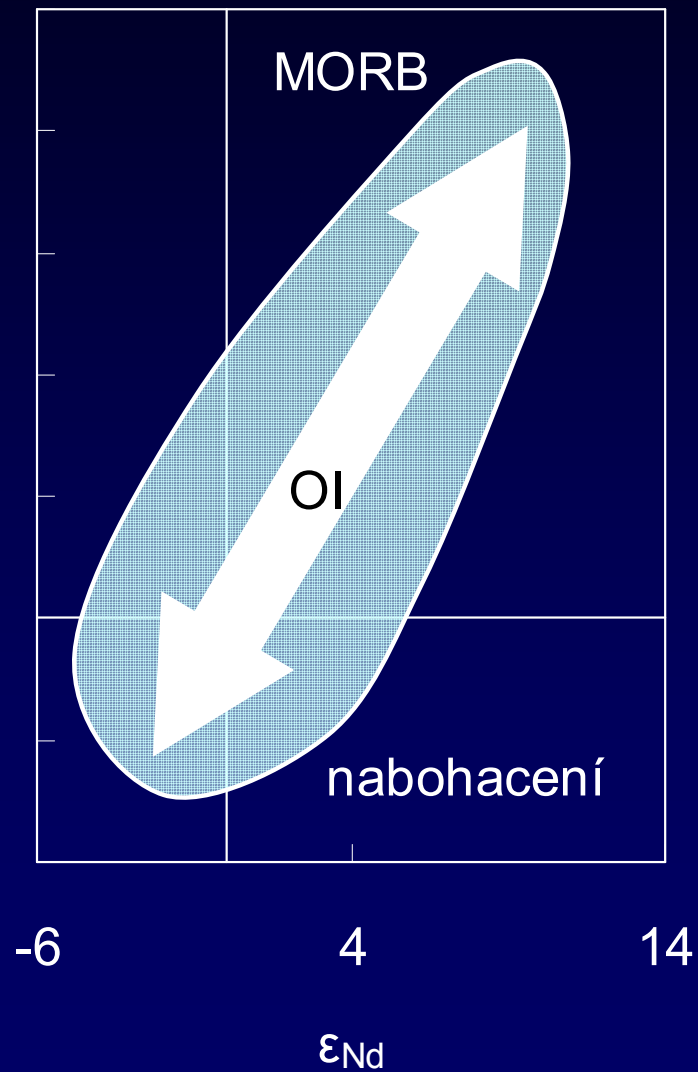
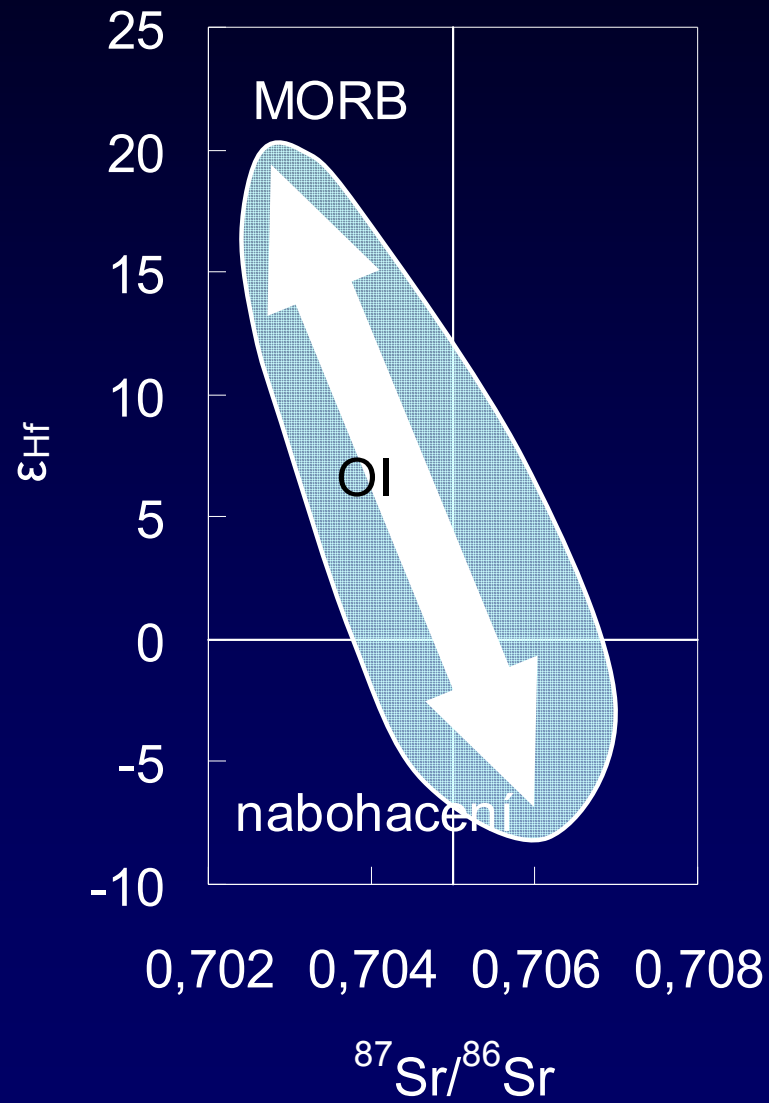
$$\epsilon_{\text{Nd}} = \frac{\frac{^{143}\text{Nd}}{^{144}\text{Nd}} - \left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{\text{chondr}}}{\left(\frac{^{143}\text{Nd}}{^{144}\text{Nd}}\right)_{\text{chondr}}} \times 10^4$$

poměr vůči chondritu

# Kombinace různých izotopů



# $^{176}\text{Lu}-^{176}\text{Hf}$



# U-Th-Pb

$$\frac{{}^{207}\text{Pb}}{{}^{204}\text{Pb}} = \frac{{}^{207}\text{Pb}_0}{{}^{204}\text{Pb}} + \frac{{}^{235}\text{U}}{{}^{204}\text{Pb}} \left( e^{\lambda_{235}t} - 1 \right); \quad \frac{{}^{206}\text{Pb}}{{}^{204}\text{Pb}} = \frac{{}^{206}\text{Pb}_0}{{}^{204}\text{Pb}} + \frac{{}^{238}\text{U}}{{}^{204}\text{Pb}} \left( e^{\lambda_{238}t} - 1 \right)$$

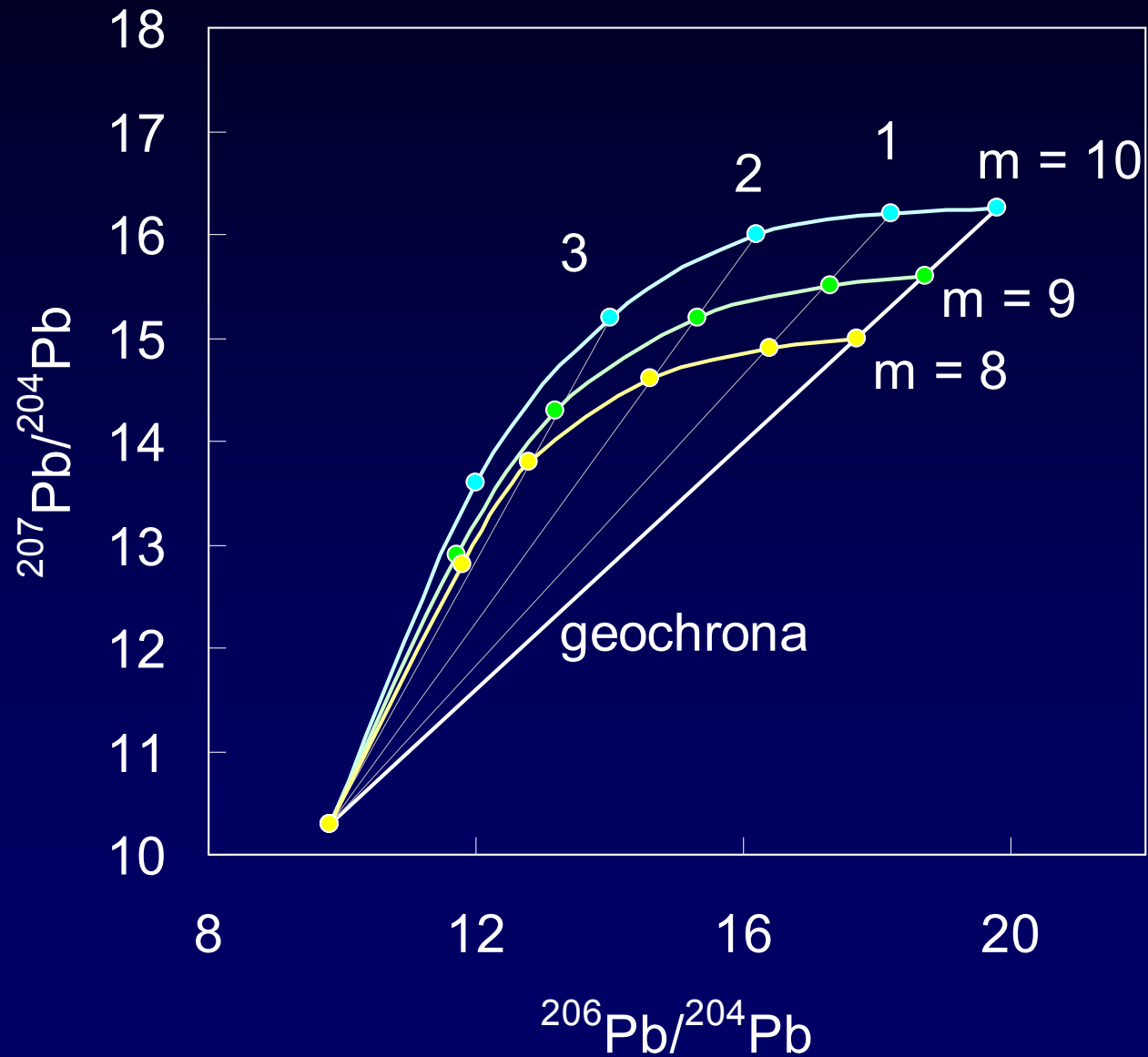
$$\mu = \frac{{}^{235}\text{U}}{{}^{204}\text{Pb}}; \quad \kappa = \frac{{}^{232}\text{Th}}{{}^{238}\text{U}}; \quad \frac{{}^{238}\text{U}}{{}^{235}\text{U}} = 137,88$$

$$\frac{{}^{207}\text{Pb}}{{}^{204}\text{Pb}} = \frac{{}^{207}\text{Pb}_0}{{}^{204}\text{Pb}} + \frac{\mu}{137,88} \left( e^{\lambda_{235}t} - 1 \right); \quad \frac{{}^{206}\text{Pb}}{{}^{204}\text{Pb}} = \frac{{}^{206}\text{Pb}_0}{{}^{204}\text{Pb}} + \mu \left( e^{\lambda_{238}t} - 1 \right)$$

$$\frac{\frac{{}^{207}\text{Pb}}{{}^{204}\text{Pb}}}{\frac{{}^{206}\text{Pb}}{{}^{204}\text{Pb}}} = \frac{1}{137,88} \frac{\left( e^{\lambda_{235}t} - 1 \right)}{\left( e^{\lambda_{238}t} - 1 \right)}$$



# U-Th-Pb



# Kinetika

Aktivita – počet rozpadů za minutu

$$\frac{dN_i}{dt} = -\lambda_i N_i$$

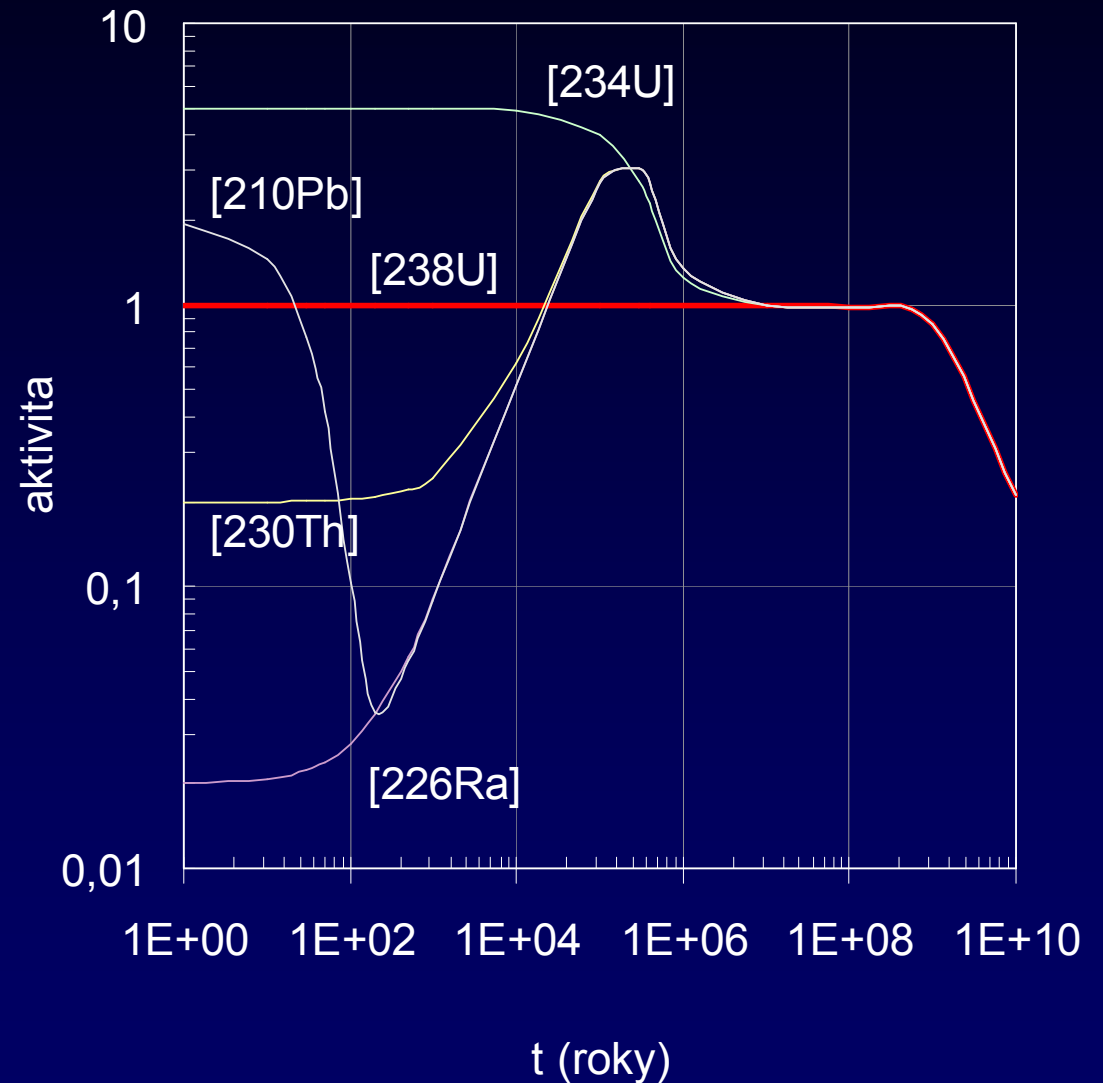
$$0 = \lambda_P N_P - \lambda_D N_D \quad \text{stacionární stav}$$

$$\frac{dN_i}{dt} = \lambda_P N_P - \lambda_D N_D \quad \text{obecně}$$

Pro rozpadovou řadu  $^{238}\text{U}$



(2) a (3) rychlé



Aktivita U se po miliardy let prakticky nemění, aktivita všech meziproductů bez ohledu na výchozí stav zhruba po milionu let dosáhne stejné hodnoty jako  $^{238}\text{U}$

# Kinetika – určování dynamiky

Určování dynamiky růstu Mn nodulí  
pro sedimenty ( $^{230}\text{Th}$  izolováno do sedimentu)

$$^{230}\text{Th} = ^{230}\text{Th}_s + ^{230}\text{Th}_u \quad \text{s - supported by U, u - unsupported}$$

$$^{230}\text{Th} = ^{238}\text{U} + \left( ^{230}\text{Th}_0 - ^{238}\text{U} \right) e^{-\lambda_{230}t}$$

$$\frac{^{230}\text{Th}}{^{232}\text{Th}} = \frac{^{230}\text{Th}_0}{^{232}\text{Th}} e^{-\lambda_{230}t} + \frac{^{238}\text{U}}{^{232}\text{Th}} \left( 1 - e^{-\lambda_{230}t} \right)$$

$$t = \frac{z}{s}$$

$$y = ae^{\frac{k}{s}} + be^{\frac{k}{s}}$$

Růst Mn nodulí

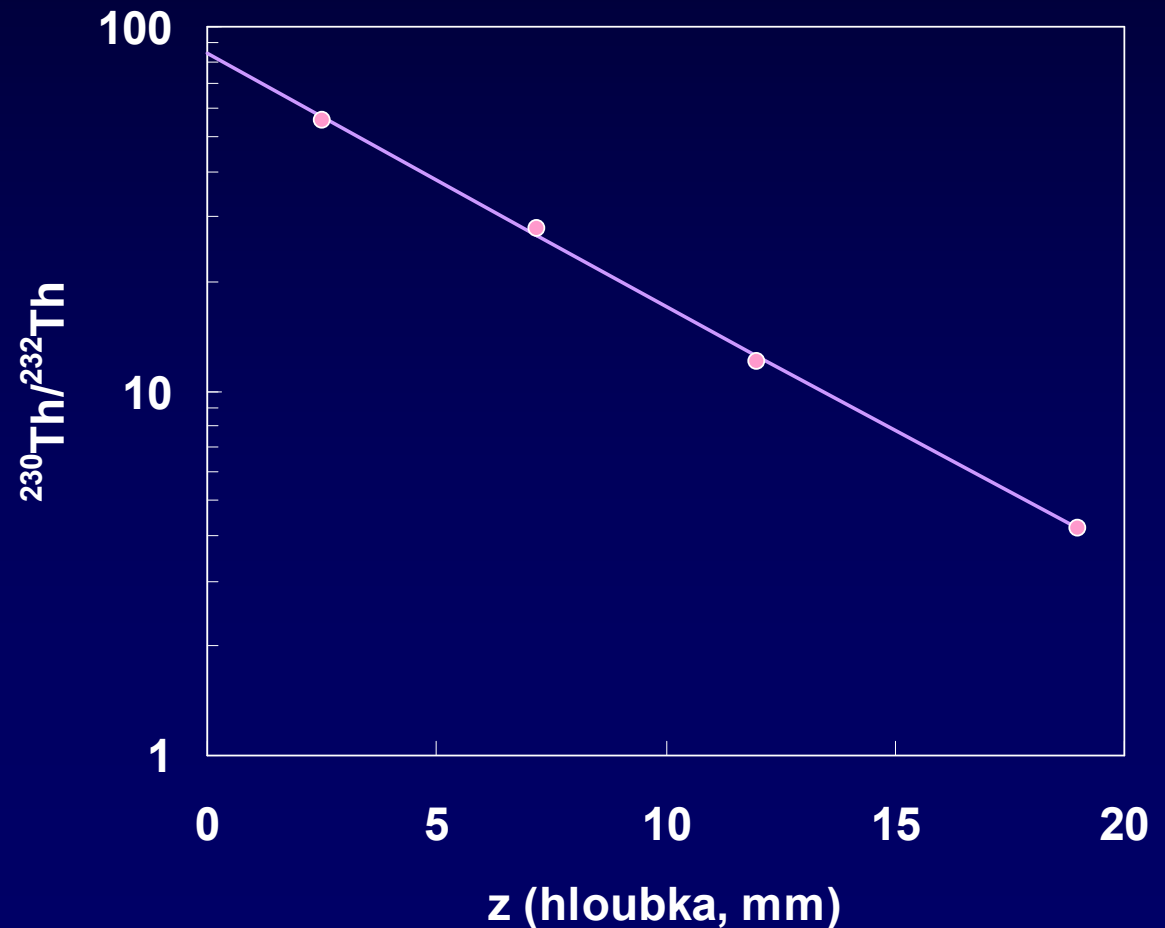
podle Huh a Ku (1984), lokalizace MANOP

$$\left( \frac{^{230}\text{Th}}{^{232}\text{Th}} \right)_0 = 84,25$$

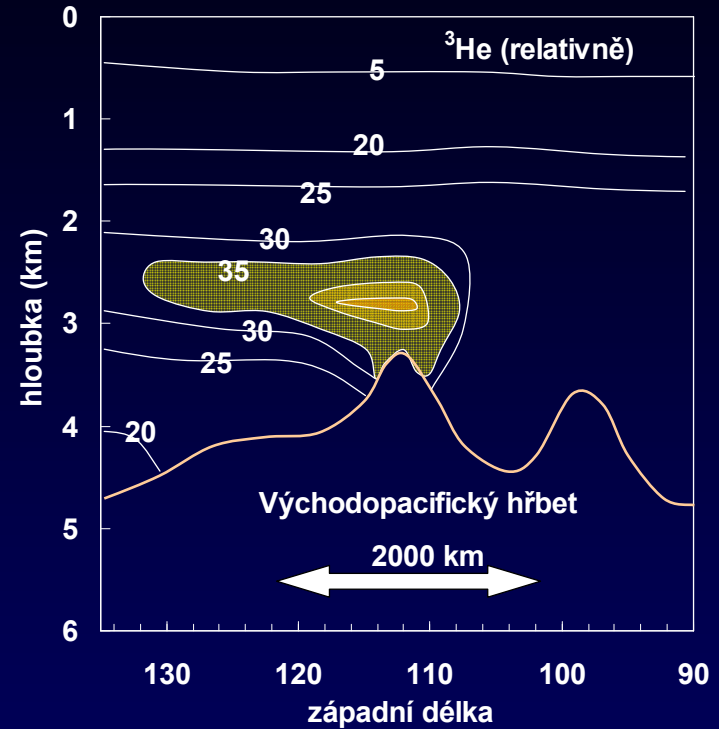
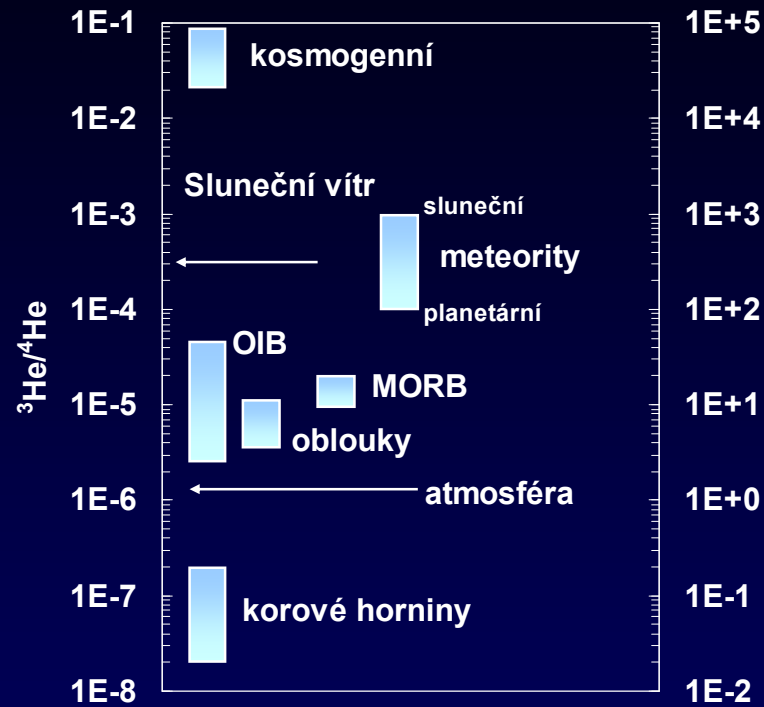
$$\left( \frac{^{238}\text{U}}{^{232}\text{Th}} \right) = 0,22$$

$$s = 5,73 \times 10^{-5} \text{ mm/rok}$$

$$S = 57,3 \text{ mm/mil. let}$$



# $^3\text{He}/^4\text{He}$



# $^{14}\text{C}$

kosmogenní původ, až 40.000 let, atmosféra konst.  $^{14}\text{C}/^{12}\text{C}$ , po izolaci od atmosféry

$$\frac{^{14}\text{C}}{^{12}\text{C}} = \frac{^{14}\text{C}_0}{^{12}\text{C}} e^{-\lambda_{14}t}$$

$$\lambda_{14} = 0,1209 \times 10^{-3} \quad \left( t_{1/2} = 5730 \text{ let} \right)$$